

CLAIMS

What is claimed is:

1. A multi-staged gas turbine engine fuel supply system comprising:

5 a plurality of fuel injectors,
 at least first and second staged fuel injection
circuits in each of the fuel injectors,
 each of the first and second staged fuel
injection circuits having first and second fuel
10 injection points,
 at least first and second fuel nozzle valves
controllably connected to the first and second staged
fuel injection circuits respectively,
 a fuel supply circuit including a single fuel
15 supply manifold connected in fuel supplying
relationship to all of the fuel nozzle valves,
 the first and second fuel nozzle valves being
operable to open at different first and second crack
open pressures respectively, and
20 all of the first and second fuel nozzle valves
controllably connected to a single fuel signal
manifold in a signal circuit.

2. A system as claimed in Claim 1 further
comprising each of the fuel injectors having a valve
25 housing containing one each of the first and second
fuel nozzle valves.

3. A system as claimed in Claim 2 further
comprising a single fuel supply connector in each of
the valve housings connected to the fuel supply
30 manifold and a single fuel signal connector in each
of the valve housings connected to the single fuel

signal manifold.

4. A system as claimed in Claim 1 further comprising:

5 a differential pressure measuring means for sensing a differential pressure (DCPFN) between a signal pressure of the signal circuit and a fuel supply pressure of the fuel supply circuit,

10 a fuel controller in feedback signal relationship to the differential pressure measuring means, and

a pressure regulator for the signal circuit controllably connected to the computer fuel controller and controllingly connected in signal pressure supply relationship to the signal circuit.

15 5. A system as claimed in Claim 4 further comprising:

a fuel pump connected in fuel supplying relationship to a fuel metering valve,

20 the fuel metering valve connected in fuel supplying relationship to the fuel supply manifold, and

the fuel metering valve controllably connected to the computer fuel controller.

25 6. A system as claimed in Claim 5 further comprising a first pressure input line leading from between the pressure regulator and the signal circuit to the differential pressure measuring means and a second pressure input line leading from a point in the fuel supply circuit between the fuel metering valve and the fuel supply manifold to the
30 differential pressure measuring means.

7. A system as claimed in Claim 6 wherein the differential pressure measuring means is a pressure transducer.

8. A system as claimed in Claim 6 further comprising:

a pump outlet of the fuel pump,
the pump outlet connected in fuel pressure supplying relationship to the pressure regulator,
the pump outlet connected in fuel supplying relationship to the fuel metering valve, and
a pump bypass line leading from the pump outlet to a pump bypass line inlet to the fuel pump.

9. A system as claimed in Claim 8 further comprising a signal fuel return line leading from the fuel signal manifold to a signal fuel return inlet to the fuel pump and a return line orifice in the signal fuel return line.

10. A system as claimed in Claim 9 further comprising:

the fuel pump including in downstream serial flow relationship a main pump and a booster pump,
the pump bypass line inlet disposed between the booster and main pumps,
a booster pump inlet to the booster pump, and
the signal fuel return line leading from the fuel signal manifold to a signal fuel return inlet to the fuel pump at the booster pump inlet.

11. A system as claimed in Claim 1 wherein the first injection points of the first staged fuel injection circuits are tip orifices in fuel injector tips of pilot nozzles of the fuel injectors and the second

fuel injection points of the second staged fuel injection circuits are in main nozzles of the fuel injectors.

5 12. A system as claimed in Claim 11 further comprising third staged fuel injection circuits having third fuel injection points in the fuel injectors.

10 13. A system as claimed in Claim 12 wherein the third fuel injection points are in the main nozzles of the fuel injectors.

14. A system as claimed in Claim 1 further comprising:

each of the fuel injectors further comprising:
a valve housing;

15 a hollow stem depending from the housing;
at least one fuel nozzle assembly supported by the stem;

a fuel injector conduit extending between the housing through the stem to the nozzle assembly,

20 the fuel injector conduit comprising a single feed strip having a single bonded together pair of lengthwise extending plates,

each of the plates having widthwise spaced apart and lengthwise extending parallel grooves, and

25 the plates being bonded together such that opposing grooves in each of the plates are aligned forming internal fuel flow passages of the first and second staged fuel injection circuits through the length of the strip from an inlet end to an outlet
30 end.

15. A system as claimed in Claim 14 further comprising:

the first injection points of the first staged fuel injection circuits being tip orifices in fuel injector tips of pilot nozzles of each of the fuel injectors,

the second fuel injection points of the second staged fuel injection circuits in an annular main nozzle of each of the fuel injectors, and

the main nozzle fluidly connected to an outlet end of the feed strip and integrally formed with the feed strip from the single bonded together pair of lengthwise extending plates.

16. A system as claimed in Claim 15 further comprising:

the internal fuel flow passages extending through the feed strip and the annular main nozzle, clockwise and counterclockwise extending annular legs extending circumferentially from at least a first one of the internal fuel flow passages through the main nozzle, and

the first injection points of the first staged fuel injection circuits located at spray orifices extending from the annular legs through at least one of the plates.

17. A system as claimed in Claim 16 further comprising first and second sets of the annular legs having first and second waves respectively.

18. A system as claimed in Claim 17 further comprising the first waves being parallel to the second waves.

19. A system as claimed in Claim 18 wherein the spray orifices are located in alternating ones of the first and second waves so as to be substantially aligned along a circle.

5 20. A system as claimed in Claim 1 further comprising:

pilot nozzles of the fuel injectors including the first injection points of the first staged fuel injection circuits in the form of tip orifices in fuel injector tips of the pilot nozzles,

10 main nozzles of the fuel injectors including the second fuel injection points of the second staged fuel injection circuits in the form of spray orifices of the main nozzles, and

15 the second fuel nozzle valves also controllably connected in fuel supply relationship to the first fuel nozzle valves.

21. A system as claimed in Claim 20 further comprising:

20 a second spool slideably disposed within the second fuel nozzle valve and including upper and lower peripheral passages around the second spool,

a main fuel inlet port in the second fuel nozzle valve connectable in fuel supply relationship through the lower peripheral passages to a main fuel outlet port,

25 a supplemental pilot inlet port connectable in fuel supply relationship through the upper peripheral passages to a supplemental pilot outlet port,

30 the single fuel signal manifold connected in fuel supply relationship to the main fuel inlet port and the supplemental pilot inlet port,

a first spool slideably disposed within the

first fuel nozzle valve and including a third peripheral passage around the first spool,

5 a pilot fuel inlet port in the first fuel nozzle valve connectable in fuel supply relationship through the third peripheral passage to a pilot fuel outlet port,

10 the single fuel signal manifold and the supplemental pilot outlet port of the second valve connected in fuel supply relationship to the pilot fuel inlet port.

22. A system as claimed in Claim 21 further comprising:

a second spring biasing the second spool within the second fuel nozzle valve,

15 a first spring biasing the first spool within the first fuel nozzle valve, and

20 the first and second spools operably movable by differential pressures (DCPFN) between a signal pressure of the signal circuit and a fuel supply pressure of the fuel supply circuit across the first and second spools respectively

23. A system as claimed in Claim 22 further comprising:

each of the fuel injectors further comprising:

25 a valve housing;

a hollow stem depending from the housing;

at least one fuel nozzle assembly supported by the stem;

30 a fuel injector conduit extending between the housing through the stem to the nozzle assembly,

the fuel injector conduit comprising a single feed strip having a single bonded together pair of lengthwise extending plates,

each of the plates having widthwise spaced apart and lengthwise extending parallel grooves,

the plates being bonded together such that opposing grooves in each of the plates are aligned forming internal fuel flow passages of the first and second staged fuel injection circuits through the length of the strip from an inlet end to an outlet end, and

the main nozzle fluidly connected to an outlet end of the feed strip and integrally formed with the feed strip from the single bonded together pair of lengthwise extending plates.

24. A system as claimed in Claim 23 further comprising:

the internal fuel flow passages extending through the feed strip and the annular main nozzle, clockwise and counterclockwise extending annular legs extending circumferentially from at least a first one of the internal fuel flow passages through the main nozzle, and

the first injection points of the first staged fuel injection circuits located at spray orifices extending from the annular legs through at least one of the plates.

25. A system as claimed in Claim 24 further comprising first and second sets of the annular legs having parallel first and second waves respectively and the spray orifices being located in alternating ones of the first and second waves so as to be substantially aligned along a circle.

26. A multi-staged gas turbine engine fuel supply system comprising:

at least two pluralities of fuel injectors;
each of the pluralities comprising;
at least first and second staged fuel injection
circuits in each of the fuel injectors,

5 each of the first and second staged fuel
injection circuits having first and second fuel
injection points,

at least first and second fuel nozzle valves
controllably connected to the first and second staged
10 fuel injection circuits respectively,

a fuel supply circuit including a single fuel
supply manifold connected in fuel supplying
relationship to all of the fuel nozzle valves in each
of the pluralities,

15 the first and second fuel nozzle valves being
operable to open at different first and second crack
open pressures respectively;

the first and second fuel nozzle valves of the
first plurality of fuel injectors controllably
20 connected to a first fuel signal manifold in a first
signal circuit for the first plurality of the fuel
injectors; and

the first and second fuel nozzle valves of the
second plurality of fuel injectors controllably
25 connected to a second fuel signal manifold in a
second signal circuit of the second plurality of the
fuel injectors.

27. A system as claimed in Claim 26 further
comprising:

30 a first differential pressure measuring means
for sensing a first differential pressure (DCPFN1)
between a first signal pressure of the first signal
circuit and a fuel supply pressure of the fuel supply
circuit,

a second differential pressure measuring means for sensing a second differential pressure (DCPFN2) between a second signal pressure of a second signal circuit and a fuel supply pressure of the fuel supply circuit,

a fuel nozzle controller in feedback signal relationship to the first and second differential pressure measuring means and controls first and second pressure regulators, and

the first and second pressure regulators operable to control and regulate pressures through in first and second signal circuits respectively.

28. A multi-staged gas turbine engine fuel supply system comprising:

a plurality of fuel injectors,
first, second, and third staged fuel injection circuits in each of the fuel injectors,
each of the first, second, and third staged fuel injection circuits having first, second, and third fuel injection points,

first, second, and third fuel nozzle valves controllably connected to the first, second, and third staged fuel injection circuits respectively,

a fuel supply circuit including a single fuel supply manifold connected in fuel supplying relationship to all of the first, second, and third fuel nozzle valves,

the first, second, and third fuel nozzle valves being operable to open at different first, second, and third crack open pressures respectively, and

all of the first, second, and third fuel nozzle valves controllably connected to a single fuel signal manifold in a signal circuit.

29. A system as claimed in Claim 28 further comprising each of the fuel injectors having a valve housing containing one each of the first, second, and third fuel nozzle valves.

5 30. A system as claimed in Claim 29 further comprising a single fuel supply connector in each of the valve housings connected to the fuel supply manifold and a single fuel signal connector in each of the valve housings connected to the single fuel
10 signal manifold.

31. A system as claimed in Claim 29, further comprising:

the first staged fuel injection circuit being a pilot fuel circuit in an annular main nozzle,

15 the second staged fuel injection circuit being a main nozzle first fuel circuit in the main nozzle, and

the third staged fuel injection circuit being a main nozzle second fuel circuit in the main nozzle.

20 32. A system as claimed in Claim 31 further comprising:

a hollow stem depending from each of the housings,

25 at least one fuel nozzle assembly supported by the stem,

a fuel injector conduit extending between the housing through the stem to the nozzle assembly,

30 the fuel injector conduit comprising at least one feed strip having a bonded together pair of lengthwise extending plates,

each of the plates having widthwise spaced apart and lengthwise extending parallel grooves, and

the plates being bonded together such that opposing grooves in each of the plates are aligned forming internal fuel flow passages of the pilot fuel circuit and the main nozzle first and second fuel circuits through the length of the strip from an inlet end to an outlet end.

33. A system as claimed in Claim 32 further comprising:

the first fuel injection points of the first staged fuel injection circuits are tip orifices in fuel injector tips of pilot nozzles of the fuel injectors,

the second and third fuel injection points are spray orifices in main nozzle first and second fuel circuits respectively in the main nozzles of the fuel injectors.

34. A system as claimed in Claim 33 further comprising the main nozzle fluidly connected to the outlet end of the feed strip and integrally formed with the feed strip from the bonded together pair of lengthwise extending plates.

35. A system as claimed in Claim 34 further comprising:

clockwise and counterclockwise extending annular legs extending circumferentially from at least one of the internal fuel flow passages in each of the main nozzle first and second fuel circuits in the annular main nozzle,

the clockwise and counterclockwise extending annular legs of the main nozzle first and second fuel circuits having parallel first and second waves respectively, and

the spray orifices are located in alternating ones of the first and second waves so as to be substantially aligned along a circle.

36. A fuel injector comprising:

5 a valve housing,
 a hollow stem depending from the housing,
 at least one fuel nozzle assembly supported by
the stem,
 a fuel injector conduit extending between the
10 housing through the stem to the nozzle assembly,
 at least first and second staged fuel injection
circuits in the fuel injector,
 each of the first and second staged fuel
injection circuits having first and second fuel
15 injection points,
 at least first and second fuel nozzle valves
controllably connected to the first and second staged
fuel injection circuits respectively,
 the first and second fuel nozzle valves being
20 operable to open at different first and second crack
open pressures respectively, and
 the housing including a single fuel supply
connector connected in fuel supply relationship with
the first and second fuel nozzle valves and a single
25 fuel signal connector connected in pressure supply
relationship with the first and second fuel nozzle
valves.

37. A fuel injector as claimed in Claim 36 further comprising:

30 the fuel injector conduit comprising a single
feed strip having a single bonded together pair of
lengthwise extending plates,
 each of the plates having widthwise spaced apart

and lengthwise extending parallel grooves, and
the plates being bonded together such that
opposing grooves in each of the plates are aligned
forming internal fuel flow passages of the first and
second staged fuel injection circuits through the
length of the strip from an inlet end to an outlet
end.

38. A fuel injector as claimed in Claim 37 further
comprising:

the first injection points of the first staged
fuel injection circuits being tip orifices in fuel
injector tips of pilot nozzles of each of the fuel
injectors,

the second fuel injection points of the second
staged fuel injection circuits in an annular main
nozzle of each of the fuel injectors, and

the main nozzle fluidly connected to an outlet
end of the feed strip and integrally formed with the
feed strip from the single bonded together pair of
lengthwise extending plates.

39. A fuel injector as claimed in Claim 38 further
comprising:

the internal fuel flow passages extending
through the feed strip and the annular main nozzle,
clockwise and counterclockwise extending annular
legs extending circumferentially from at least a
first one of the internal fuel flow passages through
the main nozzle, and

the first injection points of the first staged
fuel injection circuits located at spray orifices
extending from the annular legs through at least one
of the plates.

40. A fuel injector as claimed in Claim 39 wherein the annular legs have waves.

41. A fuel injector as claimed in Claim 40 wherein the waves are parallel.

5 42. A fuel injector as claimed in Claim 41 wherein the spray orifices are located in alternating ones of the first and second waves so as to be substantially aligned along a circle.